CIMET Thesis 2015

Impovements of the multimodal skin imaging prototype device "SkImager"


Jacob Bauer

16^{th} June 2015

CIMET Thesis 2015

Impovements of the multimodal skin imaging prototype device "SkImager"

Jacob Bauer[1 2] Ville Heikkinen[2] Janis Spigulis[1] Edgars Kviesis-Kipge[1]

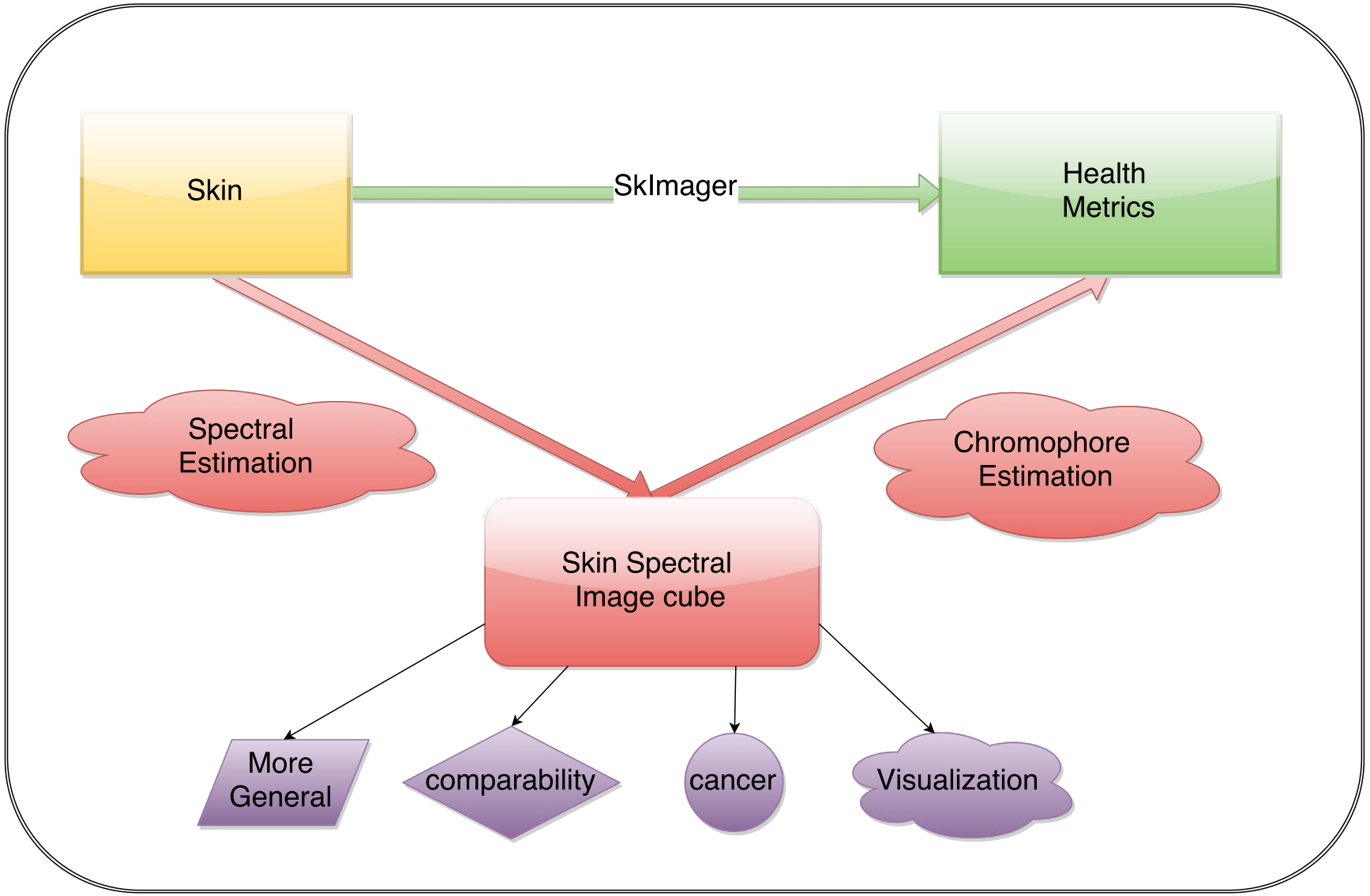
[1]Biophotonics Labrotory, Institute of Atomic Physics and Spectroscopy
University of Latvia

[2]School of Computing
University of Eastern Finland

16^{th} June 2015

Outline

Overview of the Thesis

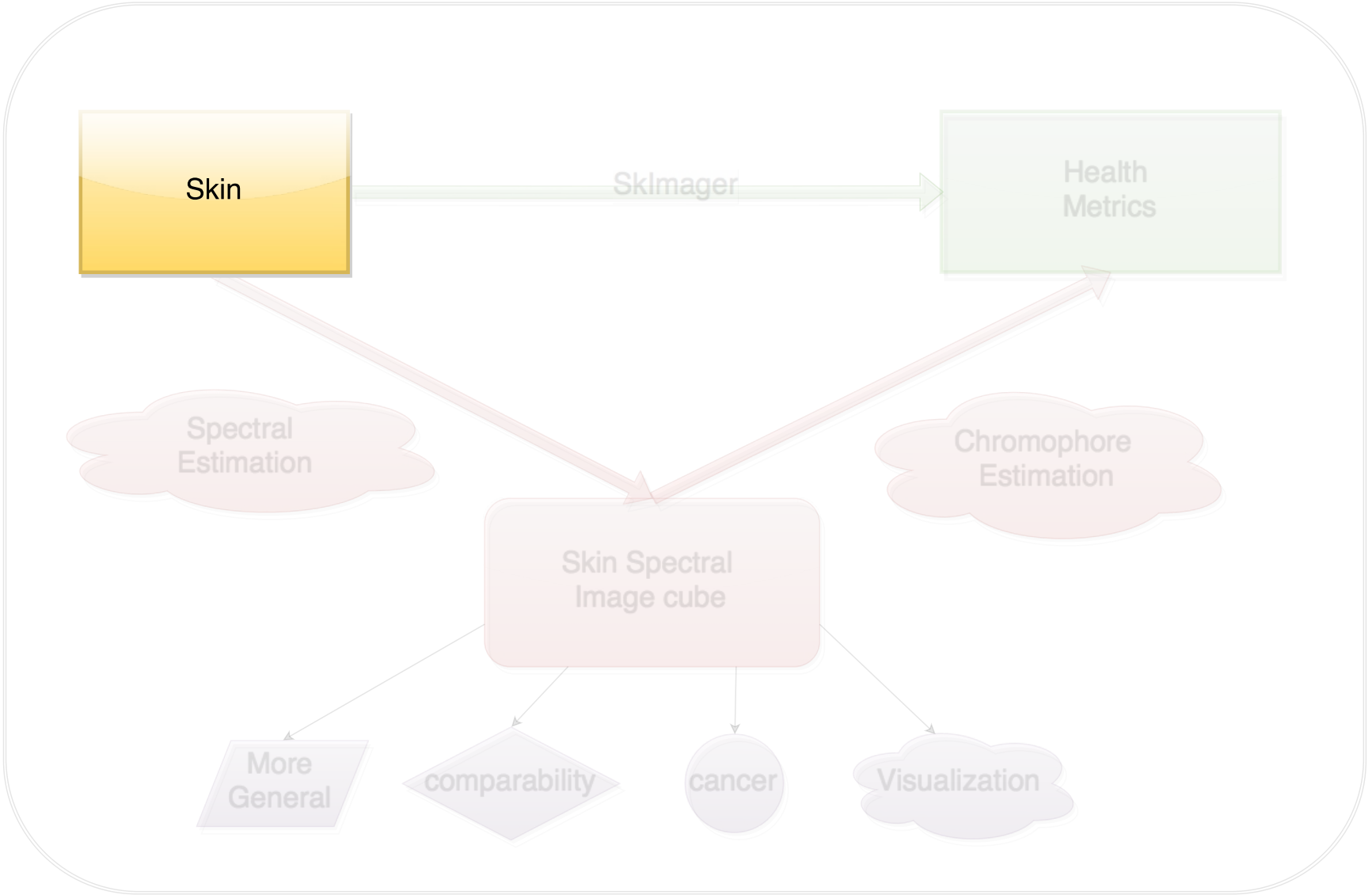


Motivation

Explore spectral estimation for a prototype non-contact optical skin assessment device

- Evaluate approaches to use the device
- Investigate computationally efficient methods to obtain more general spectral skin image data
- Demonstrate usefulness of estimations for skin assessment

Background


Skin
SkImager
Health Metrics
Spectral Estimation
Chromophore Estimation
Skin Spectral Image cube
More General
comparability
cancer
Visualization

Spectral Skin Assessment

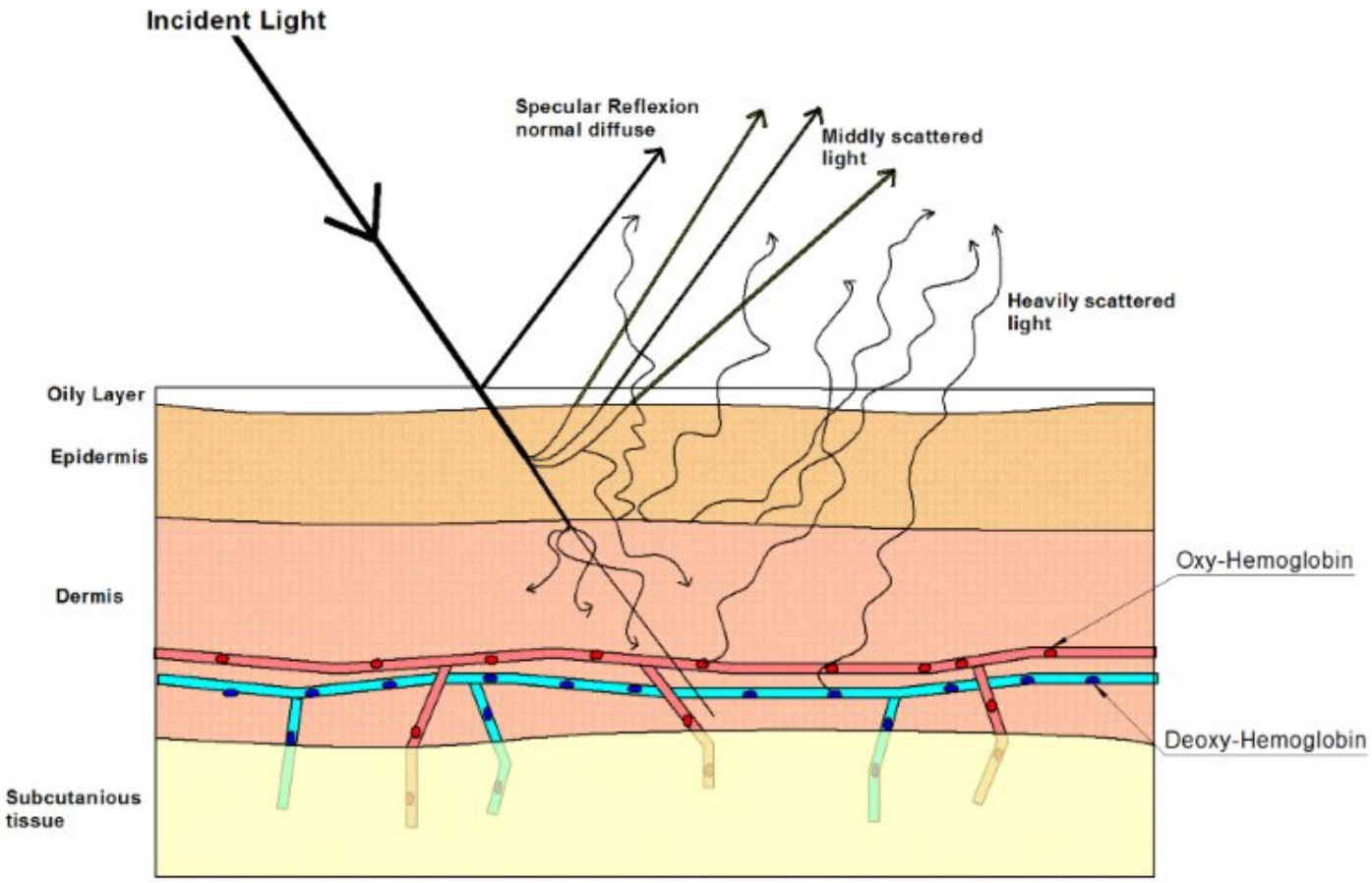


Figure: Simplified skin-light interaction model

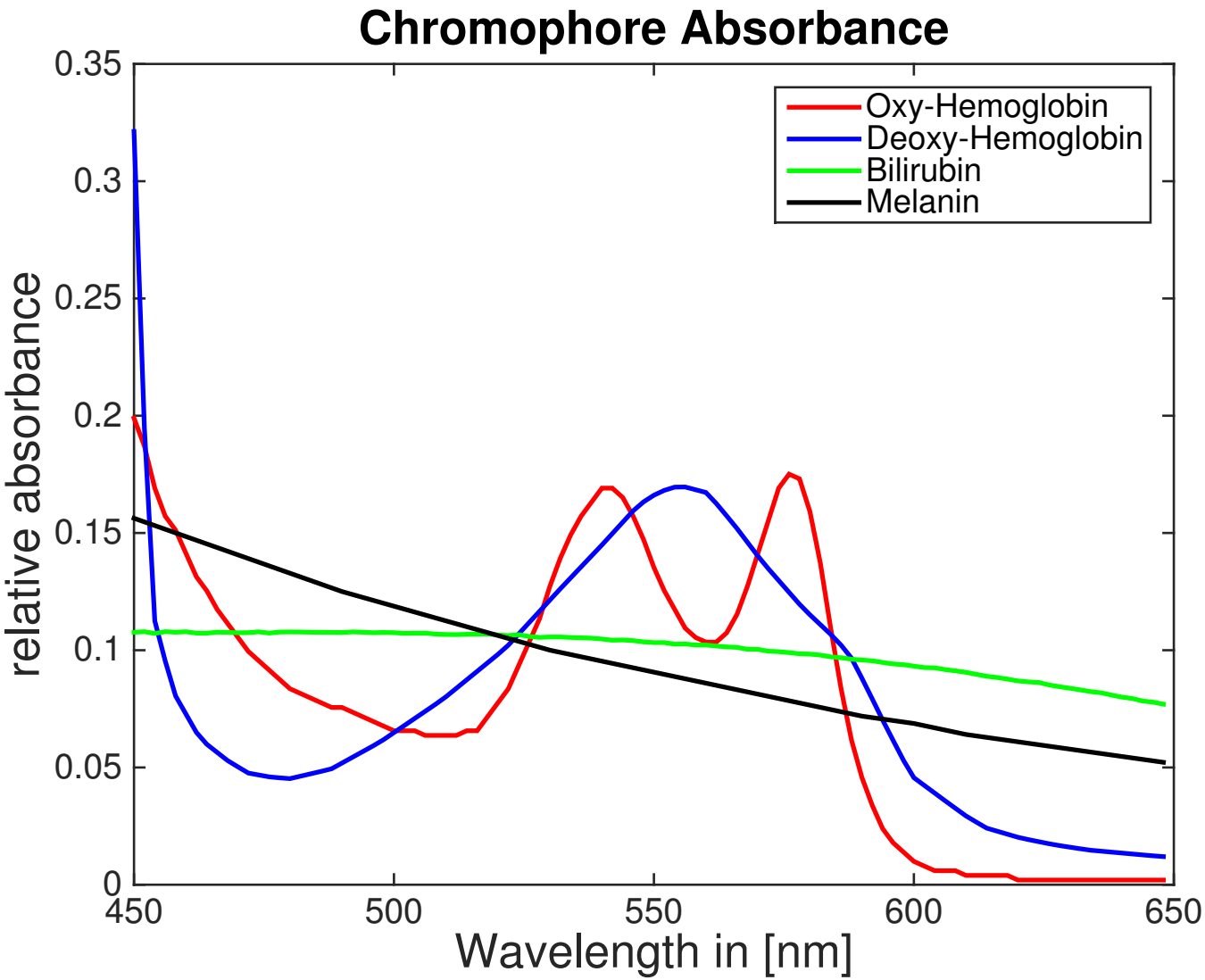
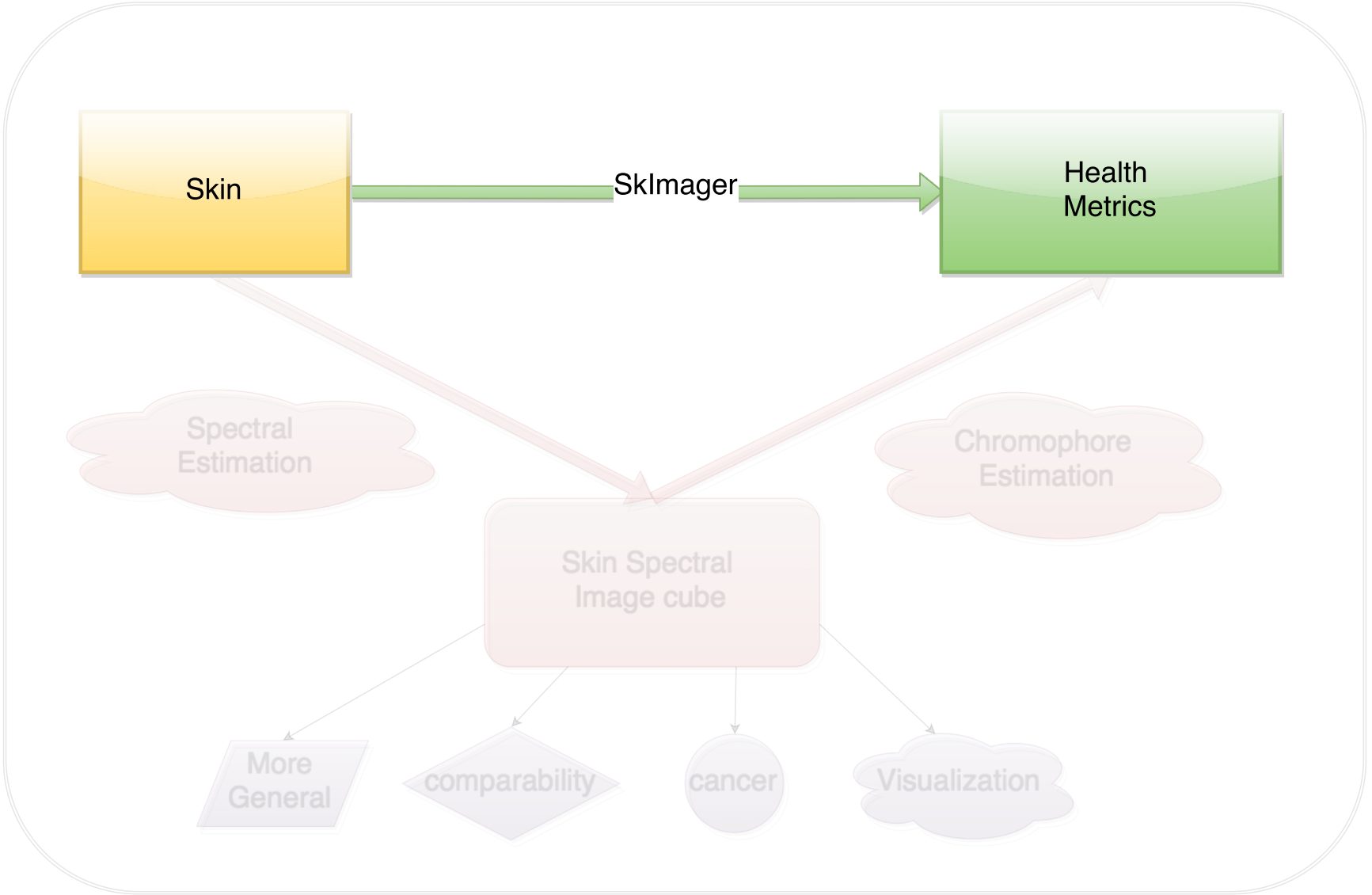
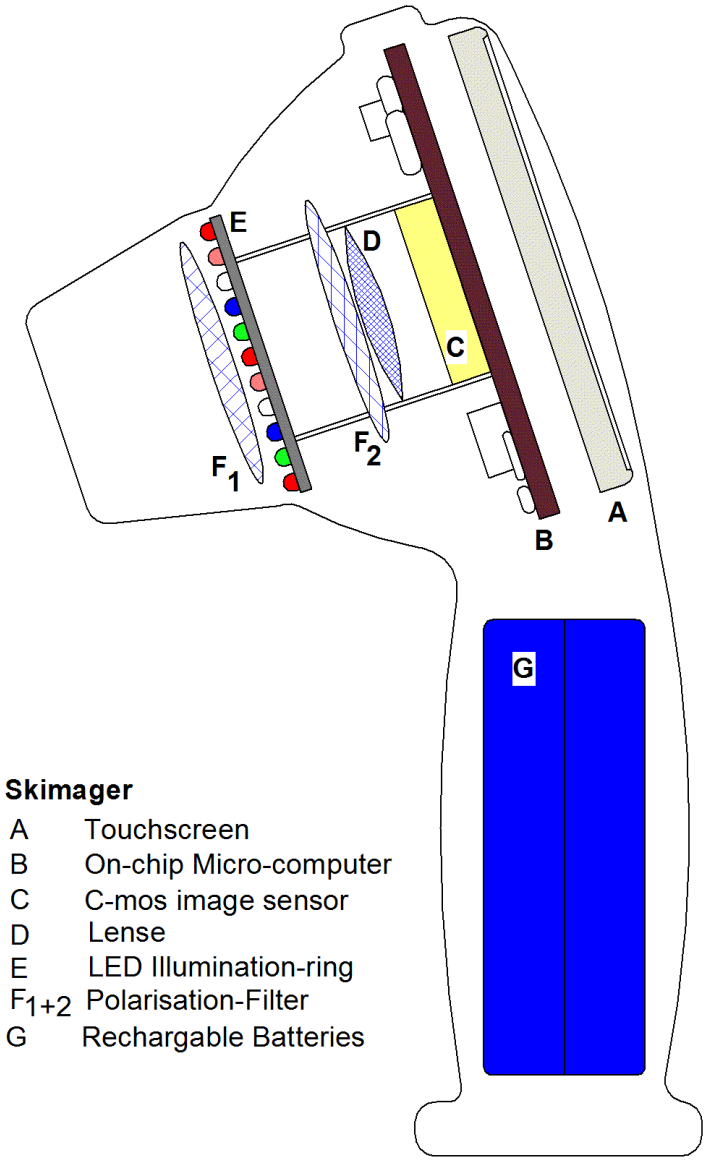


Figure: Common chromophores in skin

SkImager


Skin
SkImager
Health
Metrics
Spectral
Estimation
Chromophore
Estimation
Skin Spectral
Image cube
More
General
comparability
cancer
Visualization

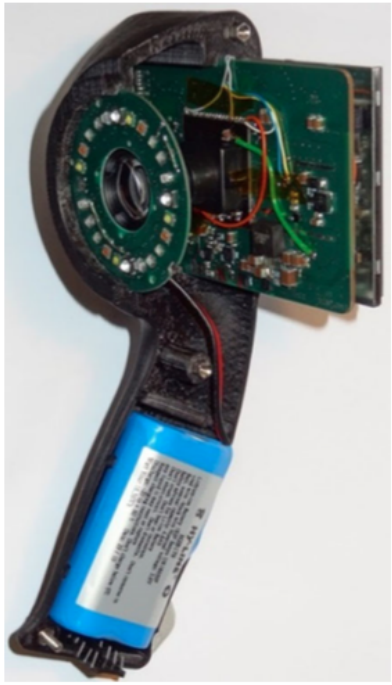
The SkImager



Skimager

A	Touchscreen
B	On-chip Micro-computer
C	C-mos image sensor
D	Lense
E	LED Illumination-ring
F_{1+2}	Polarisation-Filter
G	Rechargable Batteries

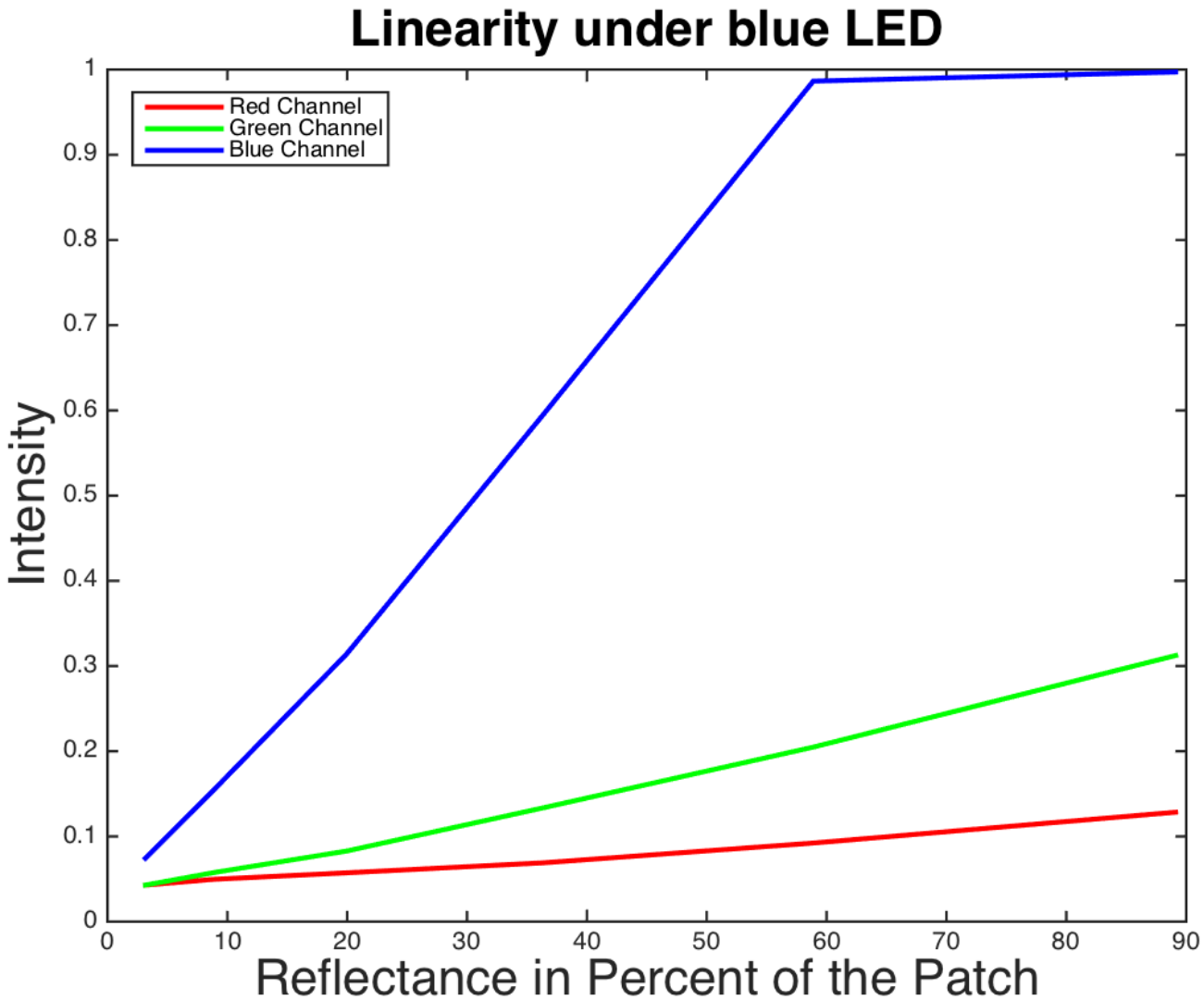
SkImager Overview



- SkImager is a proposed non-contact optical skin assessment device[1]
- Cheap sensor
- Multi illumination (5LEDs)
- Fast, easy to use,

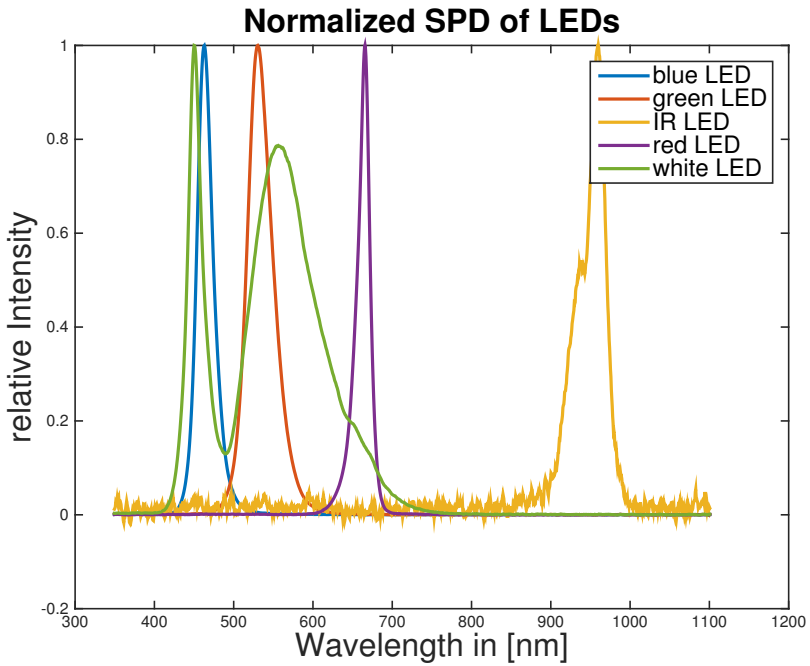
[1] Janis Spigulis et al. "SkImager: a concept device for in-vivo skin assessment by multimodal imaging". In: *Proceedings of the Estonian Academy of Sciences* 63.3 (2014), pp. 213–220

Linearity of the channels



Spectral properties of the SkImager

a)



b)

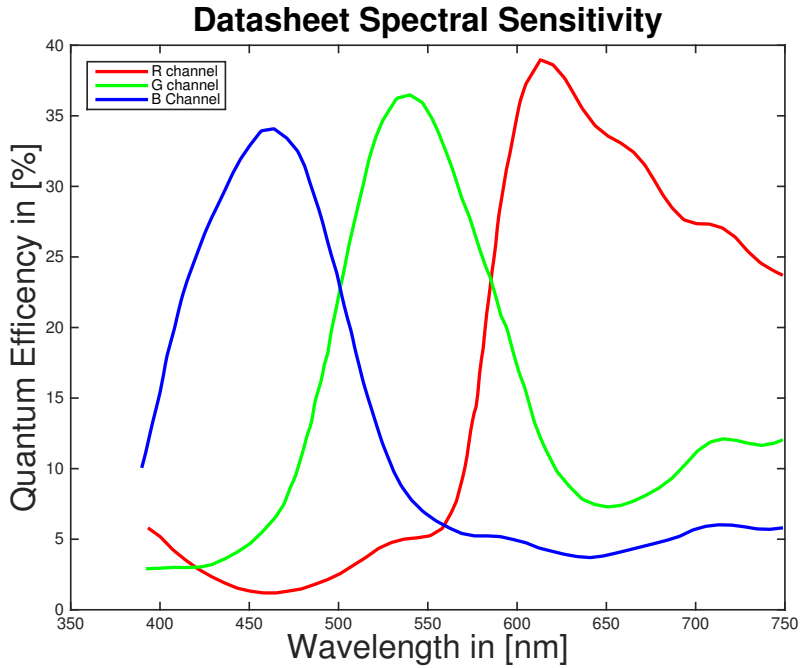


Table: a)Measured normalized LED SPD b) Datasheet sensitivities of the CMOS Sensor[3]

[3] *1/2-Inch 3-Megapixel CMOS Digital Image Sensor.* MT9T031. Rev. E 5/11 EN. Aptina. 2006

SNR of the Channels

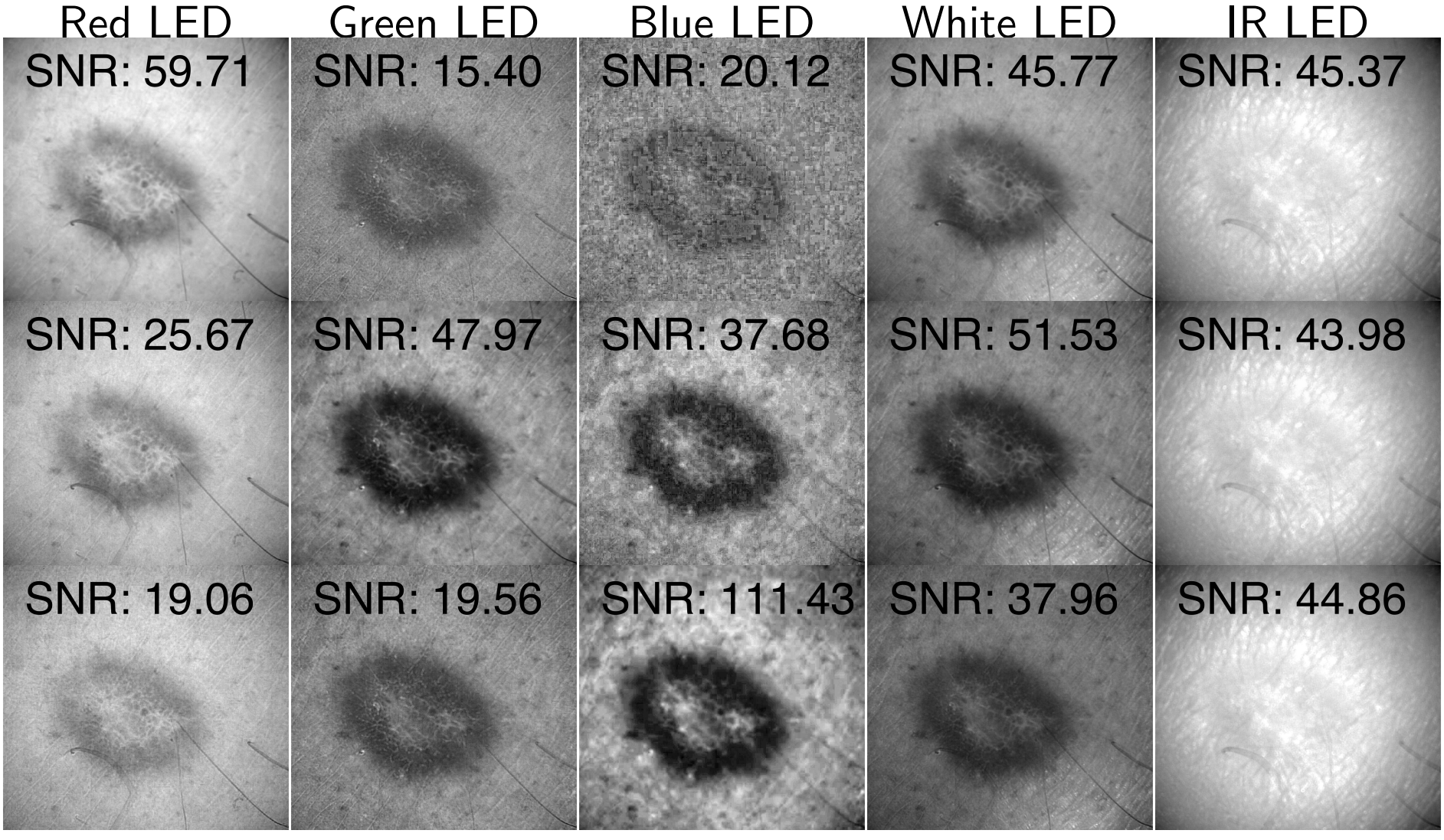


Table: All 15 channels of the SkImager with an example image

Current SkImager Channel approach

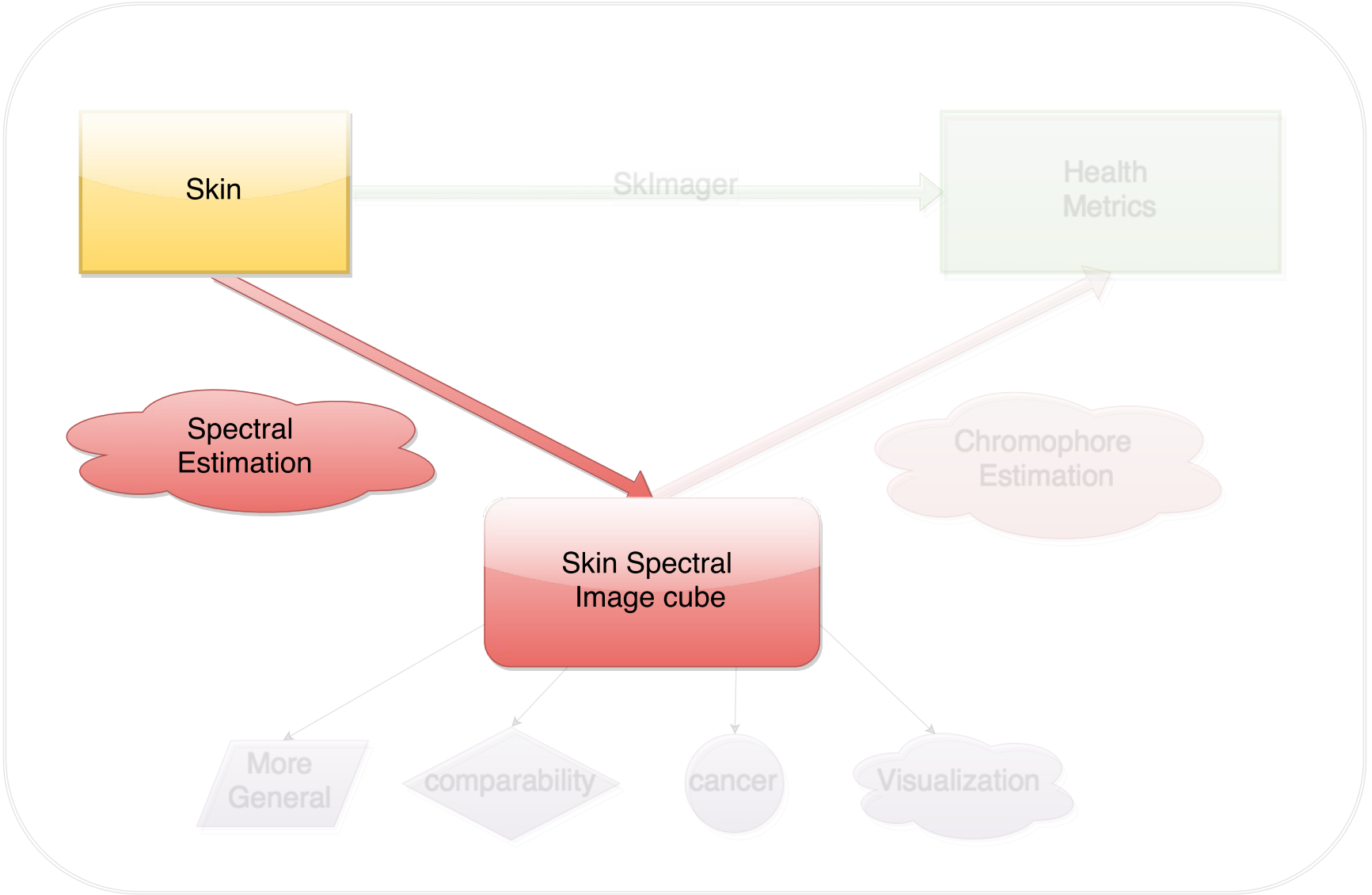
Current SkImager approach[4]

$$\begin{bmatrix} \Delta OD(R_R) \\ \Delta OD(G_G) \\ \Delta OD(B_B) \end{bmatrix} = \begin{bmatrix} m_1 & m_2 \\ m_3 & m_4 \\ m_5 & m_6 \end{bmatrix} x \begin{bmatrix} \Delta c_{OH} \\ \Delta c_{DOH} \end{bmatrix}$$

- Only uses 3 channels
- Optical Density is calculated from the channels
- Coefficients m_{1-6} are calculated considering penetration depth and aborbance coefficients for each Chromophore

[4] Dainis Jakovels and Janis Spigulis. "RGB imaging device for mapping and monitoring of hemoglobin distribution in skin". In: *Lithuanian Journal of Physics* 52.1 (2012)

Estimation


Skin
SkImager
Health Metrics
Spectral Estimation
Chromophore Estimation
Skin Spectral Image cube
More General
comparability
cancer
Visualization

Spectral Estimation Overview

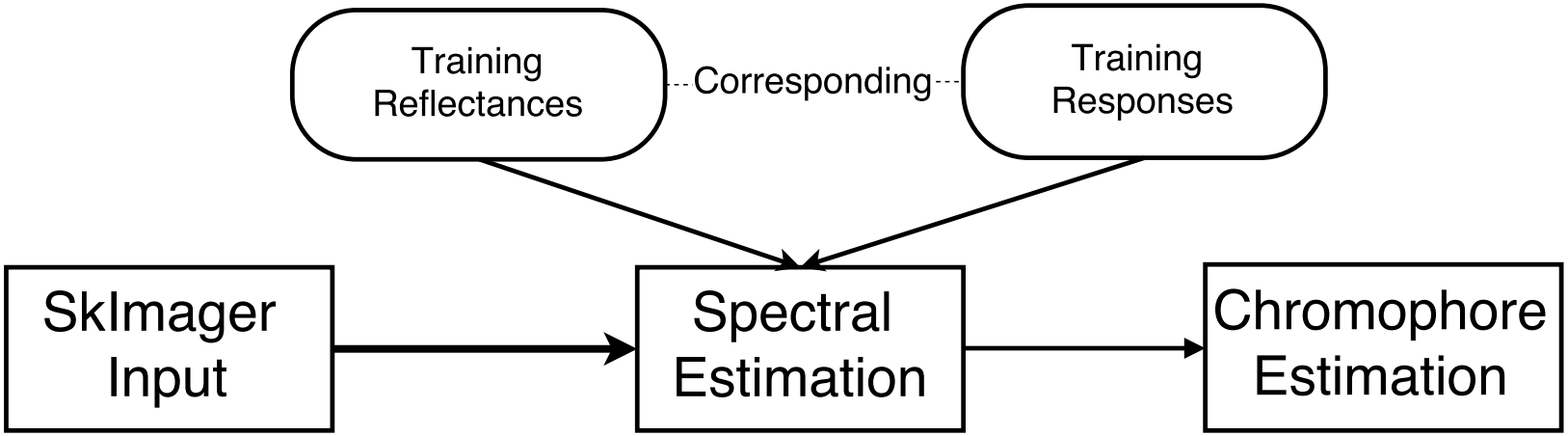
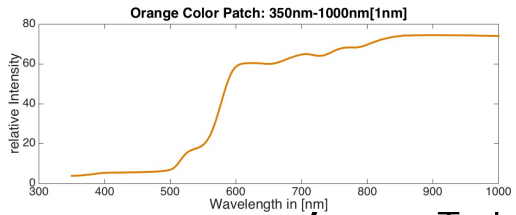
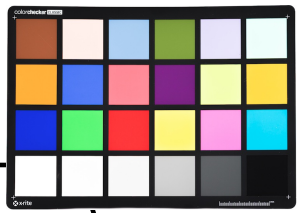


Figure: Overview of the estimation

Spectral Estimation Overview





Training Reflectances

Corresponding

Training Responses

SkImager Input

Spectral Estimation

Chromophore Estimation

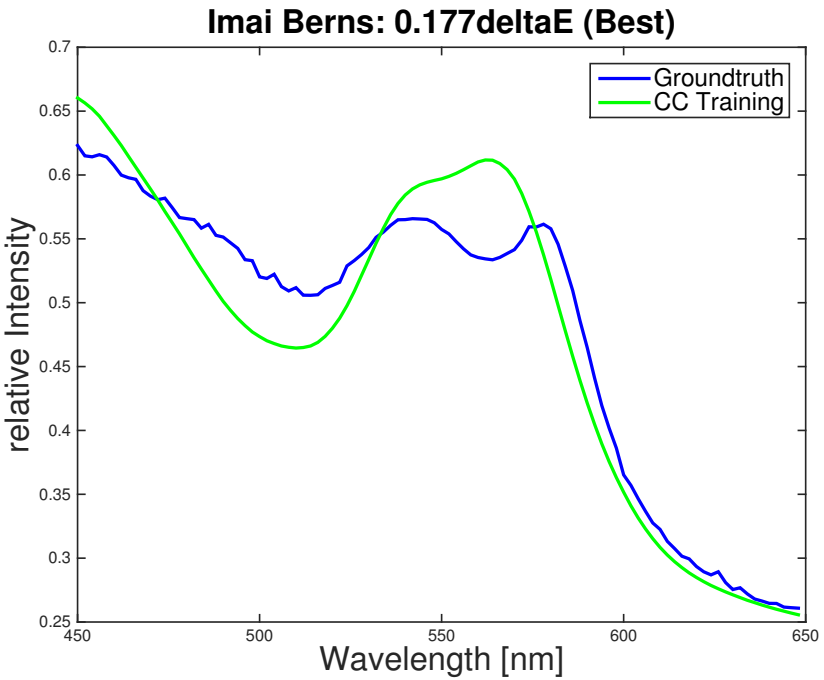
Linear Regression Estimating spectra in a low dimensional space

Imai Berns

[4] X Rite. *X Rite Colorchecker ®*. URL: http://www.xritephoto.com (visited on 06/11/2015)

Spectral reconstruction accuracy

a)



b)

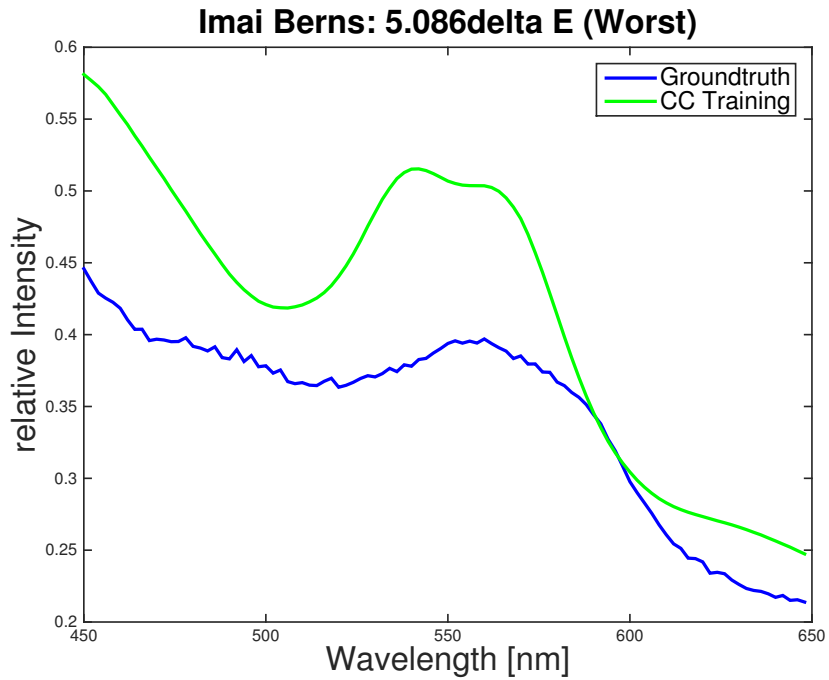


Table: a)Reconstructed spectrum (CC-training) and groundtruth (best ΔE) b) Reconstructed spectrum (CC-training) and groundtruth(worst ΔE)

Spectral reconstruction accuracy

Measure	Min	Max	Avg	Std	95%
RMSE	0.026	0.102	0.044	0.018	0.095
GFC	0.995	0.999	0.997	0.001	0.998
ΔE_{00}	0.177	5.086	1.496	0.917	3.278

Table: Spectral reconstruction tabulated values

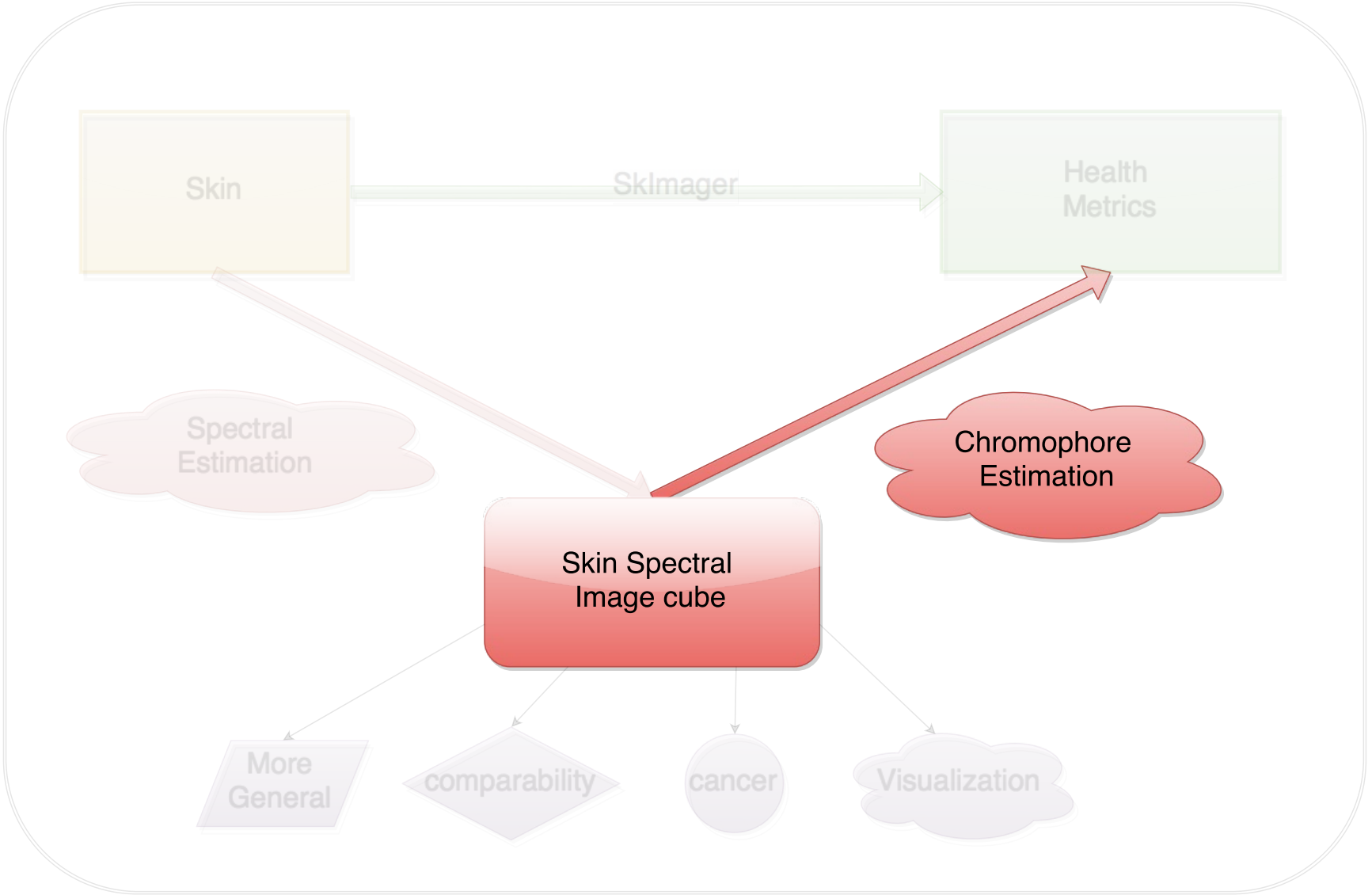
Final Normalization and Conversion

- In order to use the estimated spectra for further processing normalization was performed
- The chromophore estimation requires absorbance curves so the estimated curves are converted using

Conversion to absorbance

$$\tilde{a} = log_{10}(\frac{1}{\tilde{E}_{estimated}})$$

Chromophore Estimation



Chromophore Concentration Estimation

- Chromophore concentration (linear least square fitting) matrix model[5]

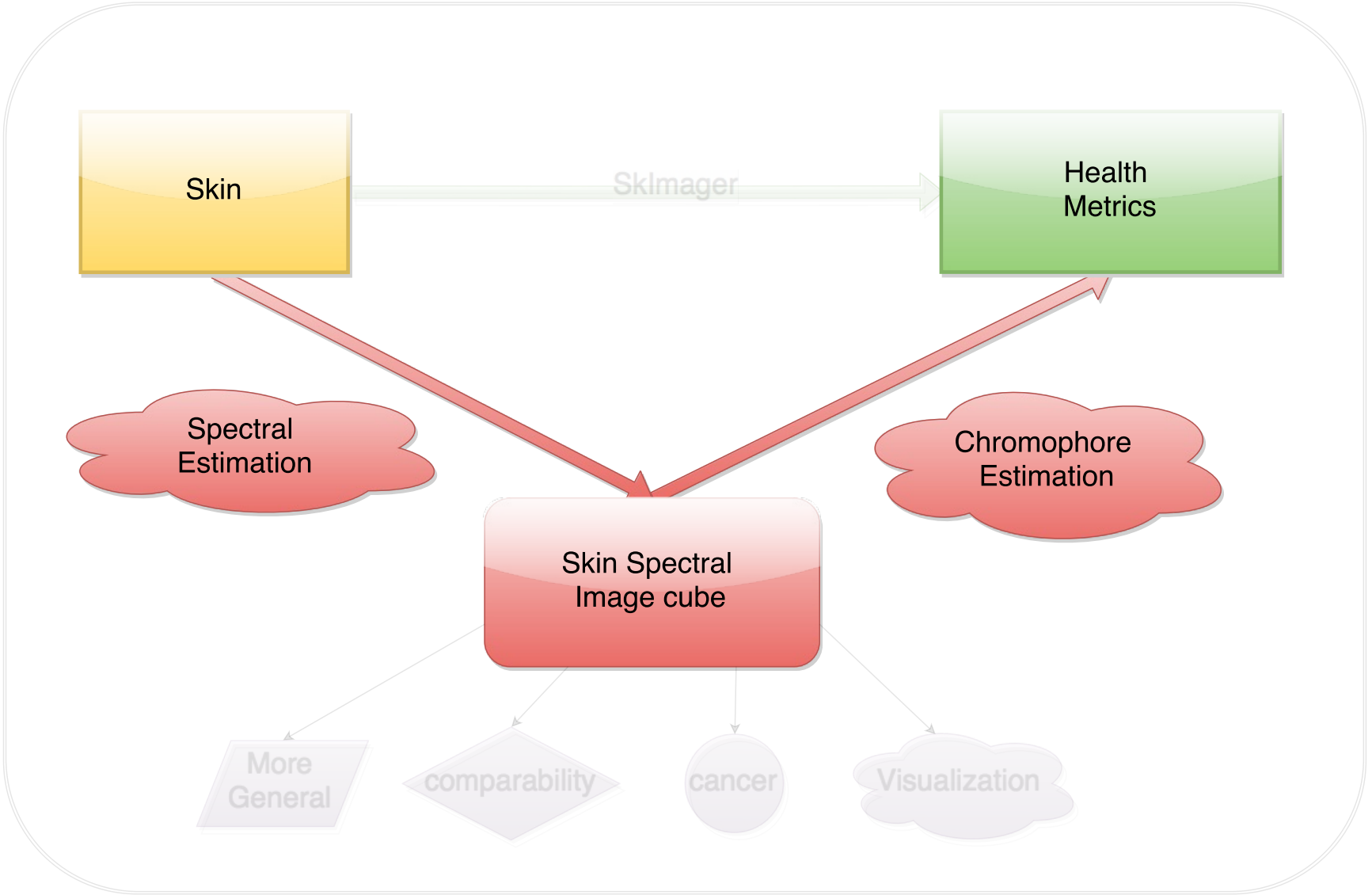
Chromophore concentration estimation

$$C = A * \tilde{E}'$$

- Requires absorbance spectra of chromophores A
- $\tilde{E}$ describes the estimated spectrum per Pixel
- The estimation is performed per pixel (chromophore map)

[5] Petri Välisuo et al. "New closed-form approximation for skin chromophore mapping". In: *Journal of biomedical optics* 16.4 (2011), pp. 046012–046012.

Estimation Results



Test Data

- Two performance evaluations were acquired
- Tests with known test results
- Occlusion measurement for Oxy/Deoxy-Hemoglobin estimation
- Bruise dataset for Bilirubin and Hemoglobin concentration

Occlusion Measurement

- Upper arm occlusion with an inflatable cuff
- 12 patients Caucasian light skinned to medium dark Caucasians (8 men, 4 female)

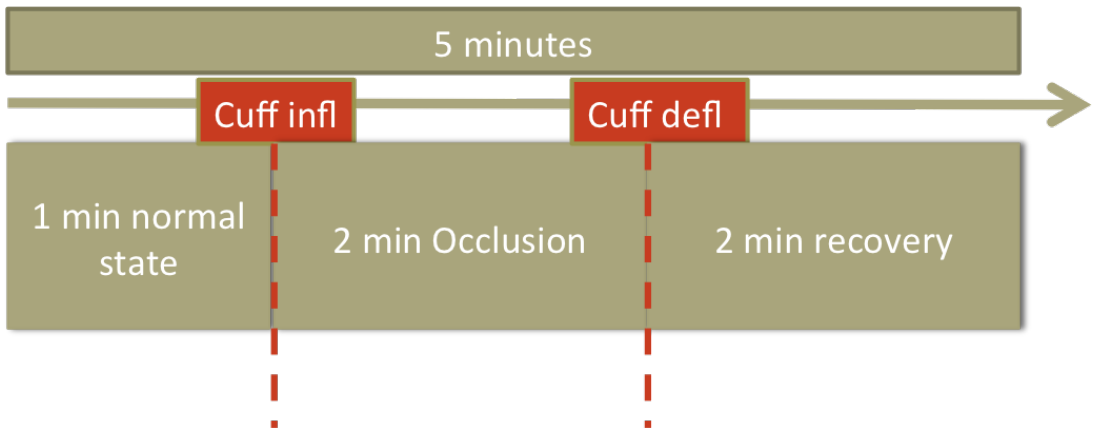
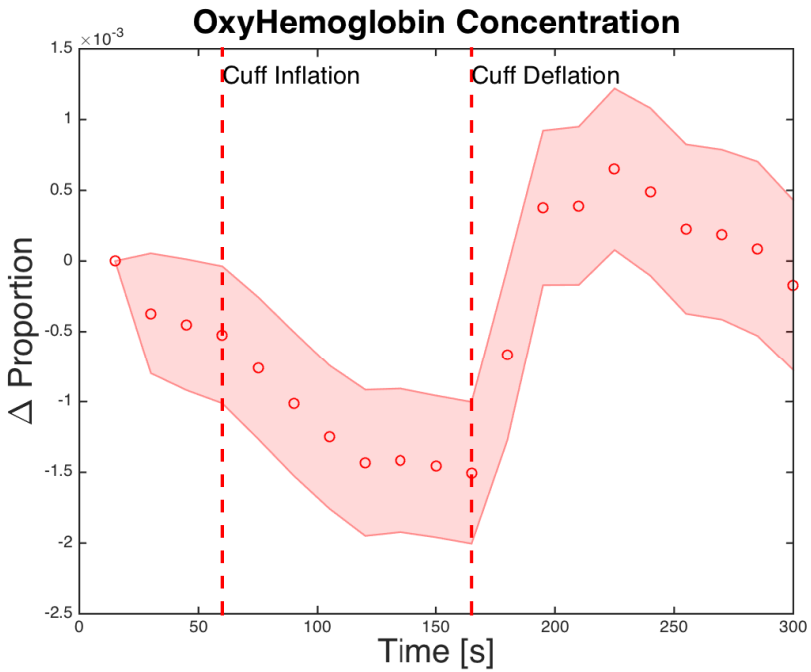


Figure: Temporal overview of the occlusion measurement

- Expected results: exponential decrease of Oxygenated Hemoglobin during occlusion, exponential increase of Deoxygenated Hemoglobin during occlusion

Results

a) Conventional channel approach



b) Estimated spectral workflow

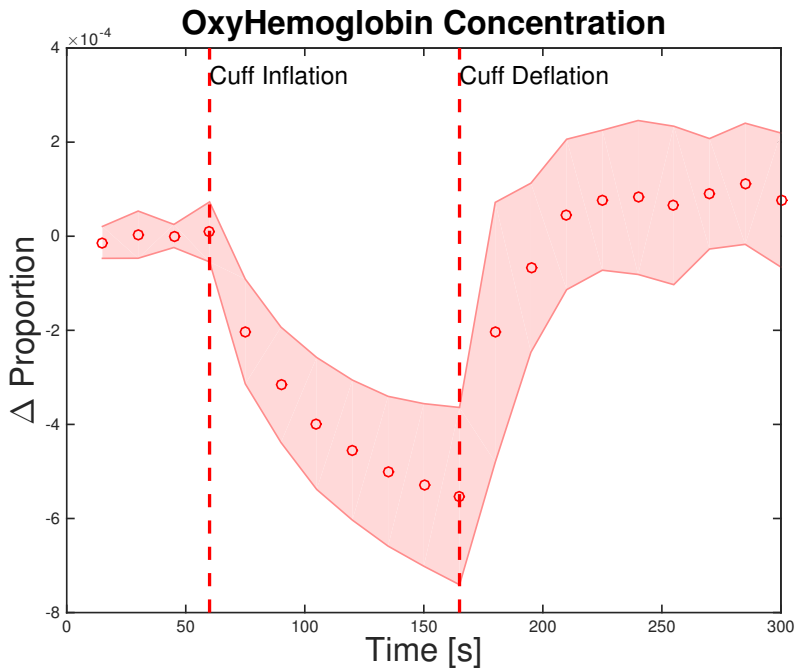
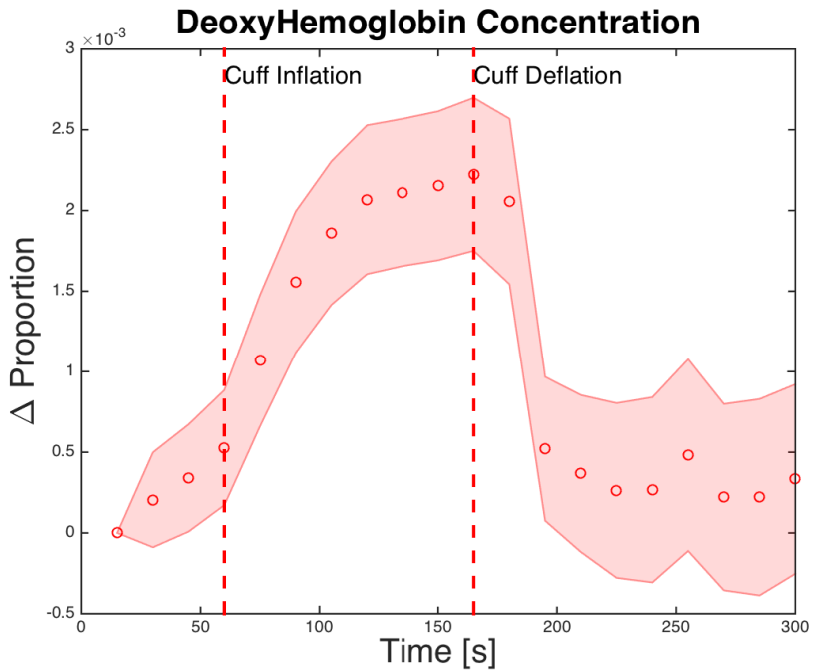


Table: a) Conventional channel approach OxyHemoglobin concentration estimated and averaged over 12 patients and b) Spectrally estimated OxyHemoglobin concentration and averaged over 12 patients using colorchecker training

Results

a) Conventional channel approach



b) Estimated spectral workflow

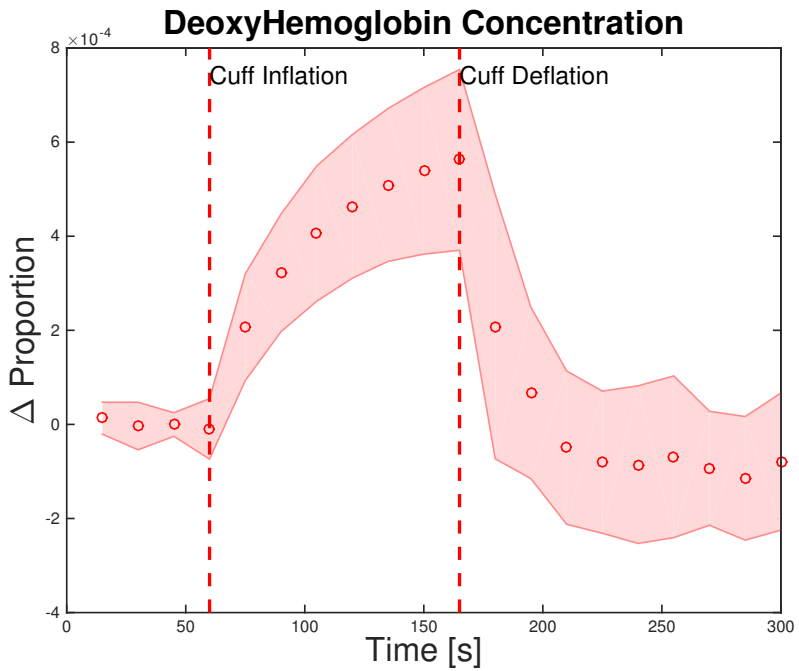


Table: a) Conventional channel approach DeoxyHemoglobin concentration estimated and averaged over 12 patients and b) Spectrally estimated DeoxyHemoglobin concentration and averaged over 12 patients using colorchecker training

Bruise Measurement

- Existing Bruise Dataset
- Patients were bruised using a paintball gun from 2m distance
- Consecutive measurements over 12 days
- Expected outcome: Hemoglobin gets decomposed (concentration decreased), Bilirubin is produced as a byproduct (increasing concentration)

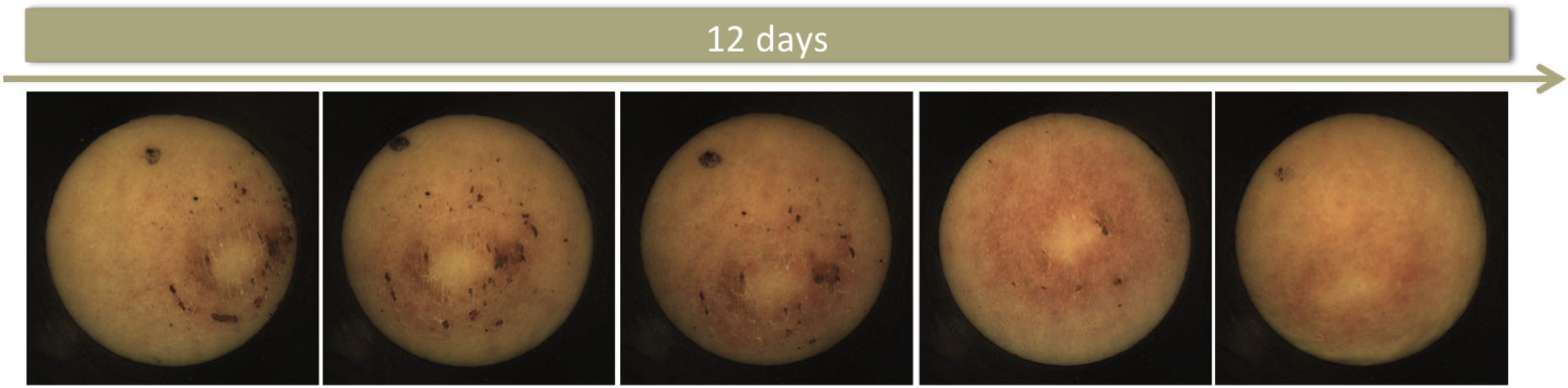
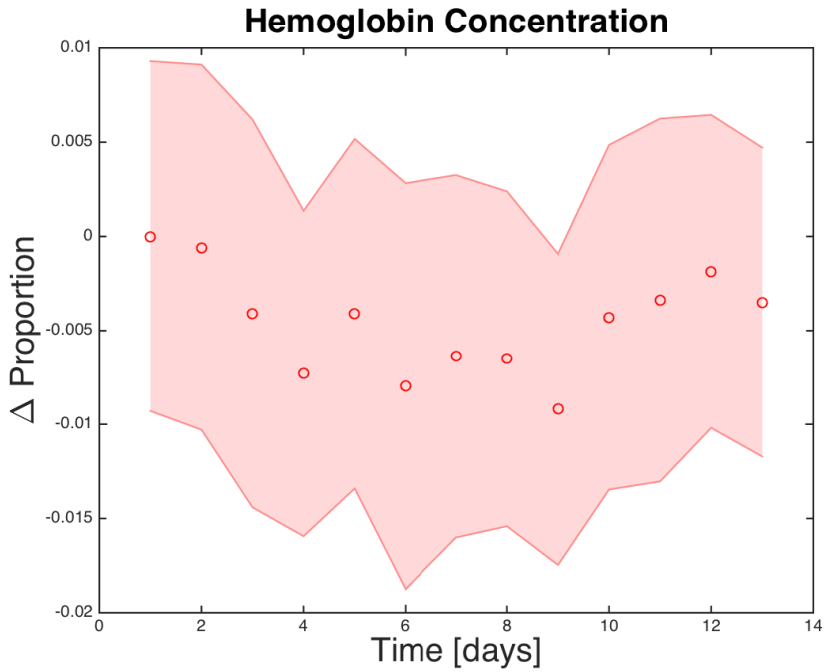


Figure: Bruise dataset example

Results

a)



b)

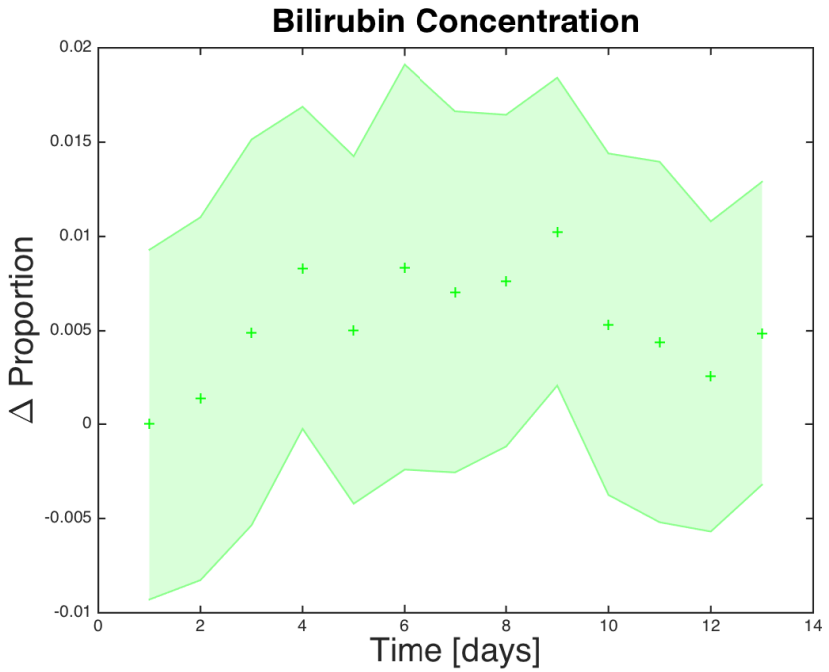
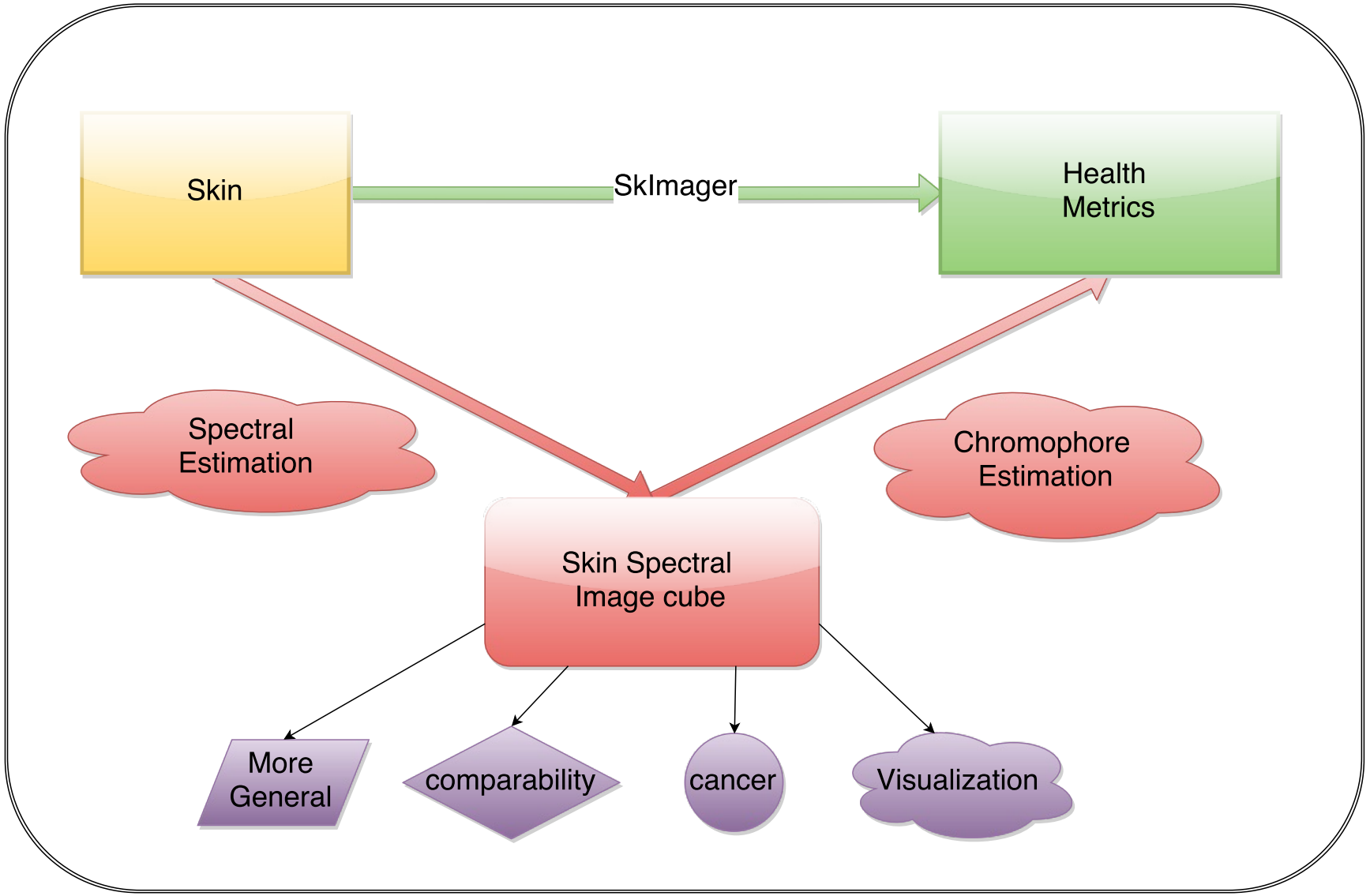


Table: a) Hemoglobin concentration over time b) Bilirubin concentration over time

Conclusions and Furthermore



Conclusion and Furthermore

Conclusion

- Spectral estimation workflow has been established for a low cost handheld skin assessment device
- Good agreement with the current data processing with two well-known experiments has been shown
- More general representation of the data has been acquired for the device

Furthermore

- Spectral estimation can be optimized, more suitable training
- More sophisticated chromophore estimation can be used
- More general estimated spectral data can be used for further analysis i.e. skin lesions, for color corrected visualization, usage of more spectral features

Questions?

This study was supported by by the Latvian National research program SOPHIS under grant agreement Nr.10-4/VPP-4/11.

This study has been presented as an oral contribution at the DOC-2015 conference and the NOP-2015 Conference

Bibliography

- *1/2-Inch 3-Megapixel CMOS Digital Image Sensor*. MT9T031. Rev. E 5/11 EN. Aptina. 2006.
- Francisco H Imai and Roy S Berns. "Spectral estimation using trichromatic digital cameras". In: *Proceedings of the International Symposium on Multispectral Imaging and Color Reproduction for Digital Archives*. Vol. 42. 1999.
- Dainis Jakovels and Janis Spigulis. "RGB imaging device for mapping and monitoring of hemoglobin distribution in skin". In: *Lithuanian Journal of Physics* 52.1 (2012).
- X Rite. *X Rite Colorchecker ®*. URL: http://www.xritephoto.com (visited on 06/11/2015).
- Janis Spigulis et al. "SkImager: a concept device for in-vivo skin assessment by multimodal imaging". In: *Proceedings of the Estonian Academy of Sciences* 63.3 (2014), pp. 213–220.
- Petri Välisuo et al. "New closed-form approximation for skin chromophore mapping". In: *Journal of biomedical optics* 16.4